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ATC (AIR TRAFFIC CONTROL) SURVEILLANCE/ COMMUNICATION ANALYSIS AND PLANNING

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16. Abstract

FAA funded ATC Surveillance/Communication Analysis and Planning activities during the period 1 June to 31 August 1972 are reported. Surveillance studies bearing upon possible courses of action to improve the performance of the present ATCRBS equipment and to equip present ARSR/ASR radars with state-of-the-art clutter reduction capability are discussed. An improved surveillance radar concept is formulated, and plans to implement this radar in a demonstration model are described. Communication studies just getting under way are outlined.

The concluding section describes two preliminary flight tests performed to validate procedural and data reduction plans for the ATCRBS transponder switched antenna tests.

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CONTENTS

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ATC SURVEILLANCE/COMMUNICATION ANALYSIS AND PLANNING

I. INTRODUCTION

This is the fourth Surveillance/Communication Analysis and Planning Quarterly Technical Summary, covering the work performed by Lincoln Laboratory under Interagency Agreement DOT-FA72WAI-242 between the Federal Aviation Administration and the United States Air Force during the period 1 June 1972 to 31 August 1972.

In this reporting period, work has continued in accordance with the definition summarized in the previous Quarterly Technical Summary. Following are the major accomplishments in various tasks during the past quarter.

Under Task A (Surveillance and Communication System Planning), we have defined the crucial questions which must be answered in developing the plan for the evolution of the surveillance and communication system from 1975 to 1995. These questions, together with a methodology to address them, are discussed in Section II-A.

An investigation of ATCRBS problems and possible corrective actions has been made. Analyses of improvements to ATCRBS resolution and of radar Doppler processing techniques have been initiated (Subtask A.2, Surveillance Continuity). Four analyses have been started under Subtask A.4 (Candidate Surveillance System Configurations): weather data collection via the primary radar, the role of primary radar, beacon system improvements, and over-all surveillance system improvements. A comparison of VHF multichannel and DABS-based data links for ATC use has begun (Subtask A.3). The review of surveillance and communication requirements, as provided to us by the Sponsor, has continued (Subtask A.1), and results are reported in some detail so that timely comments may be received. Collection of cost data to be used for subsequent economic analyses has started in cooperation with FAA.

Efforts under Task B (Definition of Improved ASR) have included an examination of various types of presently used and state-of-the-art clutter rejection techniques applicable to FAA primary radars. Related surveillance radar techniques and improvements presently being developed in both the FAA and military services were also investigated. An outgrowth of these investigations has been an S-band radar concept described in Section III. A demonstration radar utilizing a number of the state-of-the-art improvements is now being implemented.

Under Task C (Measurements on Switching Antennas), two sets of tests have been planned and coordinated, one in the Andrews/Washington sector against ARTS-III, and one against the common digitizer at NAFEC. The goal of these tests was to validate the test and data-reduction plan. Data reduction is being carried out at present. Further tests will follow with more types of aircraft, and a final test plan for these tests is being prepared for submission to the Sponsor. A substantial amount of coordination activity between the various agencies involved in the tests had to be carried out and is reported in Section IV.

II. SURVEILLANCE AND COMMUNICATION (S/C) SYSTEM PLANNING (TASK A)

A. Overview

The goal of Task A is to recommend a cost-effective, time-phased, technical plan for the development and implementation of surveillance and communication improvements, leading from the on-going enhancement programs to a fully deployed DABS-based system. The time span covered will be 1975 to 1995.

The surveillance system is defined here as the hardware and software which provide aircraft "tracks" to the Air Traffic Control system. The surveillance system includes ground sensors which measure aircraft position, airborne transponders which operate in conjunction with the sensors, and data processing equipment which sorts the position data, associates each datum with a previously established track (or initiates a new track), and estimates current aircraft position based on previous history and the new information.

This definition differs from the traditional definition (which is narrower) for several reasons. Consider first the implications of ATC automation. In the nonautomatic environment, raw data from sensors are displayed to the controller (he is the "tracker"); in the NAS (en route) and ARTS (terminal) environments, a digital tracker is used to provide aircraft labels to the controller's scope; eventually, the digital tracker will provide inputs to an automatic metering-and-spacing function, and later to automatic traffic-advisory and IPC functions. In these cases, the controller will monitor the operation of the surveillance system and supervise the decisions made by the automatic control system. Thus, the key attribute of a "good" surveillance system is its ability to provide at all times a position estimate (within specified accuracy) for all aircraft in the coverage region, without interruptions or spurious tracks. This fundamental quality, which we shall attempt to quantify, has been called "surveillance (track) continuity."

A second reason for considering the tracker as part of the surveillance system is apparent from an examination of Fig. 1. The solid lines show the information flow in a sensor which operates (as today) without information from the tracker; that is, a target is declared without prior

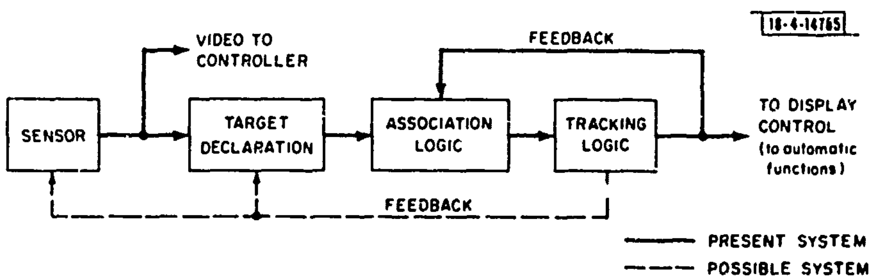


Fig. 1. Tracking with two types of feedback.

knowledge and the target report is fed to the association and tracking logic. The dashed lines indicate paths along which tracker data could be fed back to assure greater reliability of the target declaration function. This possibility is especially attractive for transponder replies carrying a digital identification. Note that it is not our intention to develop better smoothing algorithms (a problem which, in our opinion, is well understood) but rather to study the tracker as a subsystem, and examine the relationships between the tracker and the various types of sensors

(ATCRBS/DABS, primary radar). A major part of Task A involves making recommendations regarding the sensor subsystems. These subsystems represent a substantial investment by the FAA and, most importantly, interface directly with airspace users (air carrier, general aviation, and military). It is obvious that the design (and thus cost) of the surveillance sensors and the design of the airborne equipment are closely interrelated.

The choice of airborne equipment is a matter of the greatest importance. In fact, the ground system at any given site can evolve through a series of improvements and changes, each having an implementation cycle of a few years. The benefits of an improvement are immediately felt in the coverage area of a sensor, and typically it is not necessary to make the same improvement everywhere at the same time. Changes in airborne equipment, on the other hand, require long implementation times and often the quality of surveillance (and thus the reliability of ATC service does not improve substantially until a large number of users have adopted the new equipment (see, for example, the installation of altitude-reporting transponders as a means of achieving more reliable separation in "mixed airspace"). The implementation cycle for airborne equipment is probably of the order of 15 to 20 years. In the absence of regulatory action, this is related to the mean lifetime of aircraft (which are amortized over 20 years[1]).

The above implementation cycles have two important consequences, which are taken as assumptions in our study:

(1) The surveillance system must be planned so that, <u>at most</u>, one new generation of transponder equipment is required between the years 1975 and 1995.

(2) The ground segment of the surveillance system must be planned as an orderly series of upgrades, consisting of evolutionary improvements or of totally new installations, amortized over a period of 15 to 20 years,[1] in order to obtain a cost-effective implementation plan.

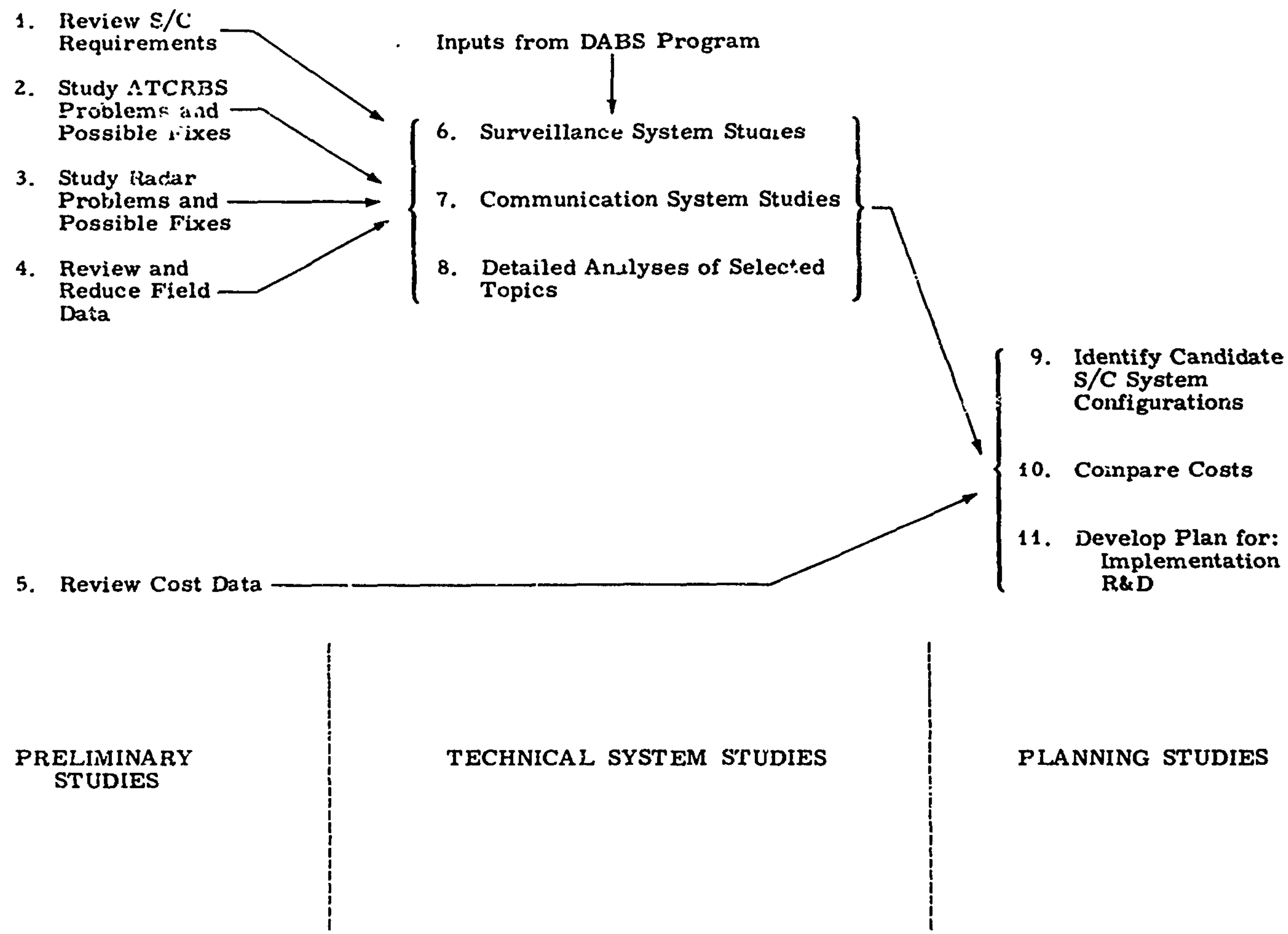
The first statement follows from the assumption that regulatory pressure for the adoption of airborne equipment will not increase <u>substantially</u>* over the present. Note that, if avionics replacement time were comparable to the replacement time of aircraft and if adequate ATC service were provided to users during the transition phase, the burden placed on users would be acceptable.

The communication aspects of our analysis are important because there are impending decisions by the air carriers to adopt a digital link in the VHF band for housekeeping and company data. At the same time, the DABS surveillance concept permits using the surveillance channel for transmission of ATC data. Several questions then arise. Should the DABS data link be used for airline carriers? Should some or all ATC data be sent via the VHF data link? Can low-cost VHF data-link equipment be developed for general-aviation use? What are the options from a system standpoint and for each airspace user? What are the technical, economic, and operational implications for the users and the ATC system? What are the consequences of each option on the ground system interfaces? How will the ATC communication load be split between voice and data links? These questions and the underlying options are being examined in detail under Subtask A.3.

* The presently planned regulations on equipment requirements and airspace use do not, in our opinion, invalidate assumption (1). A "substantial" increase in regulatory pressure would be, for example, a regulation imposing certain types of avionics for aircraft certification.

TABLE 1

FLOW DIAGRAM FOR SURVEILLANCE AND COMMUNICATION STUDIES



Let us now consider the methodology for this work, focusing attention on surveillance. First, we must define what we mean by a "cost-effective and time-phased technical plan." We propose a plan that will answer these questions:

(1) At what level of ATC service and traffic is a certain surveillance system improvement unable to provide "adequate" surveillance continuity?

(2) Which are the specific deficiencies causing this loss of continuity and how can they be corrected?

(3) How will these corrections interface with others that become necessary when the level of ATC service and/or traffic increases further?

(4) At what point in this evolutionary sequence should DABS be implemented?

(5) What changes to the present system will ease the transition?

Our plan is to provide a technical and economic rationale for the deployment of ground and airborne equipment. The deployment strategy for ground equipment will be stated in terms of "deploy the following improved or new system when the level of ATC service and/or the level of traffic reach the following thresholds." These questions will be addressed to the extent that our funding and time permit; specific situations will be examined as examples whenever possible.

Our approach in developing the technical and economic rationale for the surveillance and communication system from 1975 to 1995 is summarized in Table I.

Several projects (Items 1 through 5) involve gaining an understanding of S/C requirements, the present system, and its costs. The effort then branches into the more detailed analysis of crucial topics and, simultaneously, the consideration of the broad system issues in surveillance and communication (Items 6, 7, and 8). The DABS inputs are derived from work being carried out by Lincoln Laboratory under a separate contract. In the design of large systems, one must iterate between considering requirements, performing detailed analysis of capability, and performing broad system and economic analyses. From these iterations follow the identification of alternatives and the comparison of cost and practical elements which lead to the development of a plan (Items 9, 10, and 11). The plan will recommend R&D where appropriate.

The above breakdown of items corresponds to the five subtasks in our Work Statement[2] (Requirements Review, Surveillance Continuity, Communications, Candidate System Configurations, Surveillance and Communication Planning). Item 4 (field work, done under the Surveillance Continuity Task) has decreased somewhat in scope, due to a reduction in program duration. All results summarized in the following sections are to be considered tentative.

B. Review of Surveillance and Communication Requirements (Subtask A.1)

A review of surveillance and communication "requirements," as set forth in several FAA and other documents,[3-10] has continued. Also, OSEM responded to a majority of our questions on ATC service, coverage, airspace structure, etc.[2] Traffic models are being studied by an FAA Ad Hoc Committee, but results will not be available to us in time. We have been instructed to postulate models based on previous work, to the extent required to carry out our tasks.

The term "requirements" is used loosely to indicate:

(1) The level of ATC service which must be supported by surveillance and communication as a function of time,

(2) Traffic environments,

(3) Regulatory actions which are planned or under way,

(4) Implementation schedules of ATC installations which interface with, or are part of, the S/C system, and

(5) Over-all environment and functional constraints to which the S/C system must be designed.

We are attempting to determine the impact of each requirement, environment, or constraint on the S/C system. Since some of these change as a function of time, a successful system design will allow for reasonable compromise (modification or expansion) to meet the new requirements. Thus, "understanding requirements" is more a matter of placing reasonable bounds on future environments than a matter of their precise definition.

The following is a partial summary of requirements for the period 1975 to 1980, as we understand them. Comments by the Sponsor and readers are welcome.

1. Phase I, Upgraded Third Generation ATC System (1975-1980)

The period from 1975 through 1978 has been called "Phase I of the Upgraded Third Generation Air Traffic Control System."[3] By 1975, the control of medium- and high-density air traffic will be supported by semiautomation of a significant portion of the handling and display of flight plans, surveillance and flight progress data required by the controller to perform his tasks. By 1975, there will be 112 en route ATCRBS interrogators deployed in CONUS. ARTS-III equipment will have been installed at 61 major terminals, as well as at 80 to 90 smaller terminals with improved display subsystems. By 1975, it is planned that principal dependence for surveillance data will have shifted completely from primary radars to ATCRBS. Primary radars will continue to augment the beacon system to provide surveillance on those aircraft not yet transponder-equipped.

Phase I of the Upgraded Third Generation ATC System will be characterized by:

(a) Expanded use of the 4096-code, Mode 3/A transponder with Mode C automatic altitude reporting. All existing ATCRBS decoders will have been changed to permit the handling of altitude data.

(b) Significant increase in the volume of en route positive and terminal control airspace (pilot intentions known to controllers).

(c) Semiautomation, relieving the controller of manual and mental assembly of increasing quantities of information. Automatic "metering and spacing" programs will be available in the busiest terminal areas, but separation and sequencing decisions will be made by the controller.

(d) Improvement in navigation aids, point-to-point routing, and final-approach equipment in critical areas.

2. Regulatory Actions (1975-1980)

Federal Aviation Regulations, which are under review at this time, will make significant changes in airspace use and airborne instrumentation requirements, as follows:

(a) Positive control airspace for en route traffic will be lowered from 18,000 to 10,000 feet over about one-fourth of CONUS, containing approximately 65 percent of the total air traffic.[4] The proposed effective date is 1 July 1975. IFR flight plans will

have to be filed for, and a transponder will have to be carried on all flights above 10,000 feet in the affected areas.

(b) The base of certain controlled low-altitude airways in the eastern half of CONUS and between San Diego and San Francisco will be 1200 feet AGL.

(c) After rejection of a wide-ranging transponder proposal distributed on 14 March 1969, the FAA presented a new proposal,[5] containing the following significant items, on 15 April 1972:

(1) Twenty-one high-activity locations would be designated as Terminal Control Areas (TCAs). Forty-two additional terminal locations equipped with ARTS facilities would be designated as Terminal Areas (TAs).

(2) It is proposed that 4096-code, Mode 3/A transponders with Mode C automatic altitude-reporting capability will be required:

a. En Route (effective 1 July 1975):

Within positive control areas,

Within controlled terminal airspace at and above 12,500 feet MSL, excluding airspace below 1500 feet AGL.

b. Terminal Airspace (effective 1 January 1974):

"All aircraft, including helicopters, at the nine highest-activity TCAs (Atlanta, Boston, Chicago, Dallas-Ft. Worth, Los Angeles, Miami, New York, San Francisco-Oakland, Washington National)."

"All aircraft (note: helicopter excluded) at 12 high-activity TCAs (Cleveland, Denver, Detroit, Houston, Kansas City, Las Vegas, Minneapolis, New Orleans, Philadelphia, Pittsburgh, Seattle, St. Louis)."

For the 42 additional TAs: "A transponder would not be required of an IFR flight or a VFR flight being provided separation service. An improved transponder (note: an improved transponder is one with Mode C automatic altitude reporting) would be required for all other flights in the area. The altitude data provided by the transponder of aircraft not receiving separation service will assist controllers in separating controlled flights from uncontrolled aircraft. Only that vectoring airspace required for the descent and climbout operations of high performance aircraft will be encompassed."

If this regulation is implemented, an effective source of identity, beacon surveillance, and altitude data will be available in 21 Terminal Control Areas, as well as from all aircraft above 10,000 feet over one-fourth of CONUS, and above 18,000 feet elsewhere. The effect of the proposal for the 42 Terminal Areas is less obvious, since the volume encompassed is that used for descent and climbout operation, and a transponder is not required for aircraft under control.

3. Automation, Navigation, and Final Approach (1975-1980)

By 1974, 61 ARTS-III facilities (plus the equivalent at New York and Atlanta) will have been installed for support of terminal ATC. Twenty NAS facilities for en route ATC will be installed

by the end of 1975. Software deployment and operational status at these facilities will have been completed by the end of 1978 (Refs. 3-6) and will provide the following capabilities:

a. ARTS-III

(1) Automation of radar tracking at 59 of the 62 facilities, with 32 at the highest-density areas completed by the end of 1975.

(2) Automatic metering-and-spacing programs will have been completed for the 21 high-density TCAs by the end of 1975.

(3) Automated presentation of flight-progress strips at 11 high-density terminals by the end of 1977. (Note: It is not clear why this is not scheduled sooner for more ARTS-III facilities.)

(4) Beacon tracking, alphanumeric identification, ground speed and altitude readouts will be among the first outputs to the controller at each ARTS-III facility.

b. NAS En Route

(1) Initial "automation" will consist of accepting and storing flight plans, printing and distributing flight strips, and updating flight data.

(2) Automatic tracking, alphanumerics display, and automatic radar hand-offs should be in operation by the end of 1976.

(3) National flow control should be in operation by the end of 1978.

Planning[3] indicates that the "horizontal guidance in both en route and terminal areas will continue to be based on the VORTAC network (VOR/DME for civil and TACAN for military aircraft). To support area navigation and to eliminate unusable sectors at some of the existing VOR sites, many sites will be upgraded with improved VOR antennas or converted to Doppler VOR (DVOR). Precision VOR (PVOR) may be deployed to support navigation along closely spaced routes in high-density terminal areas. For final approach to the runway, the prime aid will continue to be the present VHF Instrument Landing System (ILS). Specific installations will be upgraded to meet Category II and Category IIIA requirements."

4. Air Traffic Environments (1973-1980)

The ATCAC predictions of quantities and types of aircraft for 1973 have been invalidated by the recent economic recession. There are now signs of increasing civil aircraft production, and ATCAC estimates beyond 1980 are being used for planning purposes.

The FAA Forecast Division in the Office of Aviation Economics has produced forecasts[4] for 1973 and 1978 that take into consideration the drop in sales of general-aviation aircraft in recent years and the failure to start as many airport expansion programs as were planned several years ago. The FAA numbers (annual quantities) have been converted to hourly averages for the busiest 14 or 16 hours at 77 airports in order to determine the traffic environment around 9 terminals of varying complexity. A study of material from several sources[8-10] has permitted the derivation of estimates of peak aircraft distributions for the region from Boston to Washington, D.C.

Work to further define the environment beyond 1980 is continuing and will make use of the outputs from on-going FAA efforts as soon as available.

C. Investigation of Surveillance Continuity (Subtask A.2)

Work on this subtask has continued in the direction defined in the previous QTS (Ref. 2).

In the beacon area, a review of problems and proposed corrective actions has been completed (see following Section D), and a detailed study of surveillance resolution impairment caused by synchronous garble and ways of improving it has been undertaken.

With regard to the primary radar area, a detailed analysis of track-swapping performance with and without radar Doppler data has been started. Comparison of the improvement achievable by using the Doppler measurements to associate current observations with radar tracks with the improvement derived by incorporating Doppler measurements in the tracker is being made. The value of ambiguous measurements will also be examined.

The possibility of using an existing AN/FPS-18 radar at our Millstone facility to collect radar data was investigated. The radar is not presently equipped for Doppler measurements and lacks adequate instrumentation for our purposes, and the idea was abandoned. However, a similar radar is being installed and instrumented under Task B and will permit this type of measurement to be made.

D. Possible Improvements to Beacon System

A study of the techniques of beacon surveillance has been carried out as a preliminary to developing a plan for the surveillance and communication system in the period prior to full DABS implementation. Two large areas of potential system improvement which warrant further attention emerge as a result of this study. The first involves shortcomings of the present system: antenna elevation patterns, airborne antenna shielding, ground system power and prf coordination, etc. Some improvements in this area are necessary, and these issues are currently being addressed by the FAA in several ways. The second area involves more effective use of the available downlink coding capability. Considerable improvement would appear possible in surveillance continuity, target resolution, and system capacity by more effective processing at the sensor sites, including use of the coded content of ATCRBS returns.

The improvements summarized in the following listing are possibilities not all of which are equally desirable.

1. Fixes Applicable to Beacon Transponders

(a) Require more widespread employment of transponders. Current surveys indicate that only 39 percent of the U.S. general aviation aircraft fleet is presently transponder-equipped. Installation and use of transponders on more aircraft would at least allow controllers to detect small aircraft and issue traffic advicories to controlled aircraft. Of course, increases in the transponder population would have the negative effect of increasing the level of fruit and the incidence of garbles; problems brought about by these increases would necessitate other fixes. This fix is currently being implemented by FAA on an area-by-area basis. (Aircraft in the PCA or TCA require transponders.)

(b) Require and use to advantage discrete (12-pulse) identity codes. The capability for discrete identification which results from the selective use of all 12 response pulses allows unambiguous and continuous determination of target identity and reduces the need to "squawk ident"; yet, in many areas, IFR aircraft are still routinely assigned 6-pulse ATCRBS codes, and old identification procedures are followed.

(c) Require altitude reporting of all aircraft.

(d) Require bracket responses of aircraft not equipped to report altitude. At present, aircraft with Mode C capable transponders, but without encoding altimeters, do not respond to Mode C interrogations. Slight modifications to the transponder would allow the transmission of bracket pulses in such cases. This would allow enhanced target detection which could use the additional responses to advantage in determining position. This concept is now under consideration in terminal areas by the FAA.

(e) Develop an acceptable set of minimum operational characteristics, and a mandatory periodic inspection system to ensure that they are in.

(f) Install dual antennas discriminately. Several methods of feeding these dual antennas have been proposed and tested, including parallel feed, use of dual transponders, one per antenna, switching between the two on a regular basis, and diversity switching.

(g) Employ interrogator modes not presently used to advantage. Many schemes of this sort could be used to reduce fruit and garble levels by allowing partial selective addressing of aircraft; many assignment procedures appear attractive. For example, the presently unused Modes B (17 μsec $P_1 - P_3$ spacing) and D (25 μsec $P_1 - P_3$ spacing) could be used by a portion of the total aircraft population in lieu of Modes A and C. (One such partitioning would assign Modes A and C to VFR traffic and Modes B and D to IFR; interrogation interlace might be ABCDABCD... . Assuming equal populations of aircraft, this would reduce fruit levels by a factor of two and would eliminate synchronous garble between IFR and VFR aircraft.)

(h) Employ the full information-handling capacity available on the downlink to advantage. With Mode A responses, this implies use of the X-pulse; with Mode C, pulse D_1, and certain combinations of the C-pulses can be used as well. Use of these bits would allow for use of new downlink transmission modes, such as those described in the next paragraph.

(i) Employ different types of downlink encoding. The ATCRBS return link could be used to advantage to telemeter various additional types of data, such as air-derived collision-avoidance or attitude information. The X-pulse could be employed to signify that a particular transmission was of this type rather than an ordinary Mode A or C transmission.

An additional problem amenable to this type of solution arises from the fact that in the present system the only means for correlating reported altitude information with aircraft identity is by observing that both responses come from the same range bins during the same portion of a scan. Given sufficiently high traffic density (or high levels of synchronous garble), an altitude report could be associated with the wrong aircraft. Various modified tracking algorithms (to be discussed later) could reduce the incidence of this problem; the creation of a new class of downlink message could similarly eliminate it. This type of reporting code would allow employment of several new tracking and beacon video digitizing schemes. Just as abbreviated forms of identity are employed in the present voice communication system, so too could abbreviated data transmission be employed to advantage here. For example, once initial contact has been established, the transponder could switch to a new mode in which each interrogation resulted in a combined identity/altitude reporting response. The response could, for example, consist of the C- and D-bits of the assigned identity code and the six least significant altitude reporting bits. This would result in the same altitude-reporting precision as is now obtained with Mode C

with no confusion so long as initial altitude is known to within 2000 feet. Some elementary form of altitude tracking would be required to keep track of the gross (4000 feet) altitude increments reported. The X-bit could be employed to signify that the return is of the combined (abbreviated) altitude/identity type. Many variations on this basic idea present themselves, if some additional means (e.g., the X-bit) is available to segregate different types of returns. For example, the transponder could respond to Mode C interrogations with full altitude and respond to all other (or some randomly chosen fraction of) interrogations with full identity. Conversely, the aircraft could manually shift to the abbreviated mode at the direction of the controller once its track has been established.

(j) Tighten tolerances on response delay and pulse spacing. This would allow an improvement in the range accuracy which could be achieved, as well as in the "tightness" of range correlation which could be employed in defruiters or digitizer target-detection algorithms. At this time, there appear to be no firm requirements for increased range accuracy, and other means are available for achieving the results which tighter correlation would yield.

(k) Employ pulse-to-pulse phase coherence in returns. Since several less radical modifications appear promising for this same purpose, it is questionable whether this modification is appropriate because of its cost.

(l) Tighten pulse width tolerances. Present ARTS digitizers employ the assumption that pulses longer than 0.6 μsec are the result of two overlapping pulse returns from different aircraft and generate separate target reports.

(m) Replace suppression dead-time gates with memory and other circuitry. Transponders are now designed to inhibit responses for fixed amounts of time immediately following a response or a sidelobe interrogation. This is done in order to combat reflected signals due to multipath and thus reduce the incidence of false targets, but has the additional disadvantage of causing those legitimate interrogations that occur during the dead times to be missed. The Naval Research Laboratory has developed a fix for this problem which takes advantage of the fact that reflected interrogations are received at a fixed time increment after the direct or sidelobe interrogation from one sweep to the next. Modifications required to incorporate this fix are extensive except in transponders that employ digital circuitry.

2. Fixes Applicable to ATCRBS I/R Sets

A fix involving the entire ground system would apply to roughly 1000 ATCRBS/IFF equipments. Although the cost implications of this are large, they appear favorable when compared to projected aircraft populations. Almost all interrogators are owned and operated by the Federal Government and, therefore, changes can be effected more easily than for airborne equipment. However, the requirements of civil and military operations are sufficiently different that there is no unanimity as to what changes should be implemented.

(a) Employ auxiliary antenna elements to fill coverage gaps. The use of additional directional antennas to fill vertical nulls in directional interrogator antenna patterns has been successfully employed by NAFEC in the field. Many variations on these basic ideas appear feasible and could be employed to advantage at sites with poor coverage. In most field installations, separate interrogator transmitters (and occasionally receivers) have been employed, with shared modulating pulses and combined video (when dual receivers are used).

(b) Improved site preparation. NAFEC has studied the effect of various surrounding terrain, vegetation, and fences on ATCRBS signal propagation. Various procedures have been made mandatory and should significantly reduce the incidence of reflected targets and the depth of directional antenna pattern vertical nulls.

(c) Employ "improved interrogator sidelobe suppression." This technique has been used effectively where reflecting objects are relatively close to the I/R site. It has the disadvantage of suppressing a larger fraction of the transponders and requiring additional switching circuitry; in addition, the interferometric effects of this dual transmission can cause peculiar and complex vertical lobing patterns. Improved SLS is planned for installation at all FAA ATCRBS installations; specifications for the next generation of ATCRBS I/R (the ATCBI-5) include provisions for its use.

(d) Use a modified antenna feed system to allow interrogator beam narrowing. By addition of a switchable phase shift network into the ATCRBS antenna during the transmission of the P_2 pulse, the antenna can be made to radiate that pulse with a pattern which resembles the "difference" pattern of a conventional monopulse receiving antenna, with a sharp null along the boresight. The use of this technique, together with appropriate power level adjustments, can significantly reduce the effective interrogator beamwidth.

(e) Employ monopulse techniques on receive. A study[11] of the use of sum and difference antenna pattern generation (i.e., monopulse) techniques for reception at the I/R site has concluded that the accuracy achievable through such techniques is comparable to that obtainable with the present ATCRBS digitizer beamsplitting procedure. However, an additional advantage is that the azimuth estimate could be made on the basis of far fewer returns (say, three or four). Thus, it appears to fit well with schemes such as uplink beam narrowing which are implemented to reduce interference but result in fewer returns per scan.

(f) Employ receive sidelobe suppression (RSLS). This technique is useful for combating ring-around caused by non-SLS-equipped aircraft and for combating fruit. The ATCRBS downlink has enough power margin that the fruit returns from almost all aircraft within line of sight are detected by the ground receiver in spite of antenna directivity and, consequently, most fruit returns are sidelobe-received.

(g) Employ sensitivity time control. STC is useful mainly as a fix to the sidelobe problem which appears to be disappearing due to successful application of other fixes (notably extensive deployment of SLS-equipped transponders). Its usefulness in combating fruit is limited, since fruit is not in synchronism with the interrogations.

(h) Develop and implement new ATCRBS antennas with greater vertical aperture. The vertical pattern could be designed to cut off more sharply at the horizon and thus reduce the amount of energy spilled onto the ground. Provision of the needed amount of beacon antenna aperture would probably require design of a new, unified radar/beacon antenna, with dual feed, to replace both present antennas; however, it is conceivable that in some installations a new, taller beacon antenna could be added to existing radar antennas. Other possible designs include a mechanically rotated set of back-to-back antennas (reflectors or arrays), an array of beacon antenna elements mounted on the radar reflector (as in certain airborne IFF interrogator installations), and a fixed, agile-beam beacon antenna combined with a separately mounted radar antenna. It appears that in any of these designs the sum-difference (monopulse) concepts discussed above could be readily incorporated.

In either the mechanically rotating ATCRBS phased array or the fully electronically steered array concepts, the antenna could be programmed to raise the lower edge of the beam over discrete obstacles which might cause reflections at particular azimuths within the scan. Whether the benefits that accrue from this approach (mainly further reductions in the incidence of false targets due to reflections) outweigh the extra expense of varying the phasing of elements within each column remains to be determined.

(i) Development of a new generation of beacon video processors. Numerous improvements in the beacon video processing area appear attractive, especially when considered in conjunction with other fixes described here.

(1) Amplitude/Monopulse. Amplitude information can be used to advantage in off-boresight monopulse angle estimation and in certain decoding applications where the incidence of synchronous garble is high. In either case, somewhat less receiver compression than is now employed appears desirable in order to preserve differences in received signal levels. In the monopulse case, a separate receiver for each channel would be required; gain characteristics of the two would be necessarily closely matched.

(2) Code. Other improvements that could be made to the beacon video processing procedure are based primarily on the observation that present procedures cull out much information prior to processing which could, in fact, be used to advantage in determining aircraft position and response codes. For example, the configurations of present beacon video processors are patterned after radar signal processors, which are forced to sort returns on the basis of range, differentiate between target returns and clutter by use of MTI data, and detect and determine the position of legitimate targets by recognition of certain characteristic return sequences. In the ATCRBS situation, however, all returns are "tagged" uniquely to individual aircraft (assuming proper unique assignment of beacon codes) and could be sorted on the basis of these codes. This would provide relief from problems encountered under situations of high density where present digitizers become confused by overlapping signals in a single range bin, and attempt to correlate return brackets prior to (rather than following) decoding. In addition, it would remove artificial restrictions on range resolution brought about by the range-bin sorting procedure. With the monopulse-on-receive techniques discussed above, each return would give complete target position information; even though the use of several returns would enhance the quality of that information, it would not be necessary to examine long sequences of returns in order to make a single estimation.

(3) Fruit. If return information were sorted on the basis of discrete codes, the monopulse angle estimation system could derive information on target azimuth from mainbeam fruit returns as well as legitimate returns. Thus, the process of eliminating fruit returns (and, consequently, some legitimate returns as well) could be replaced by one in which fruit is used to advantage. (As noted earlier, RSLS is probably needed to make this practical.)

(4) Tracker Feedback. An additional shortcoming inherent in the present generation of beacon video processing equipments arises from the fact that their

target detection algorithms make no distinction between new targets and targets which were detected on previous scans; the processor reacquires each target as though it were a fresh target on each scan. Even when the system knows the position of an aircraft, the data acceptance thresholds required to provide a new data point to the tracker are those associated with initial detection. Feedback from the tracker to the I/R-site-based beacon video processor, at a rate comparable to that of the target position reporting channel, could be employed to "remind" the site processor of the positions of known targets on each scan, and thus allow it to adaptively lower its detection threshold in order to take advantage of data received during periods of low round reliability. (In NAS and ARTS, that data is discarded, although a skilled controller could employ it to advantage in the manual system). This notion of feedback of aircraft position information to the beacon video processor also appears desirable in connection with decoding problems caused by partial synchronous garble.

(j) Site relocation. Relocation of radar/ATCRBS installations to properly chosen locations on higher ground might in many instances provide significantly improved low-altitude coverage with no appreciable penalty in increased incidence of vertical lobing and false targets; in conjunction with the fixes, it could in many instances reduce vertical lobing and false target problems. Whether the improved coverage to be gained warrants the cost and difficulty of new site acquisition, equipment installation, and phase-over is open to question.

(k) Development of a fully agile electronically steered antenna. The ability to control azimuth on an instantaneous basis would allow use of an adaptive interrogation rate and dwell-time that is based on the sufficiency of previous returns and on the tactical situation. An additional benefit of this sort of antenna is the ability to steer in elevation in order to raise the beam over obstructions and reflecting objects; this capability adds materially to the cost and complexity of the antenna array.

3. Fixes Applicable to the Ground System as a Whole

The principal nature of these fixes is to make the present collection of relatively loosely connected ground-based sensors more closely approach a unified, well-coordinated system and some of them are presently in progress.

(a) Effective management and control of pulse repetition interval. FAA has recently implemented a procedural program under which offending sites can at least be tracked down and identified rapidly. However, further control appears necessary, and this sort of management function will continue to be required for the foreseeable future.

(b) Effective management of interrogator power. FAA has implemented a program to do this by installing attenuators in transmitter RF output lines. The amount of attenuation is chosen to restrict the maximum range of the ATCRBS to the assigned value.

(c) Use of fruit data based on knowledge of other interrogator timing. This fix involves the use of interrogator prf generators with improved long-term stability and timing, so that each interrogator can keep track of the timing of its neighbors. In this way, each interrogator can filter out fruit returns caused by each of its neighbors and identify them with individual aircraft.

(d) Sensor data transfer. There are several ways in which sensor-to-sensor coordination could be increased to provide improved performance with regard to missed returns, garbled returns, and over-all system accuracy; some depend on the use of fixes already mentioned. In situations where data are not received on a particular target for a time exceeding some threshold, advantage could be taken of special capabilities of any interrogator within line of sight, such as azimuth measurement, variable prf, or beam agility in an "intensive search" mode.

(e) Transfer of target situation data on request. The ability of the proposed NAS tracker to employ data from multiple sensors is limited by the registration accuracy of the surveillance system. However, certain types of information which are somewhat independent of registration errors could be profitably employed in a multi-sensor situation. For example, if each sensor maintained a track on each target, track deviation information (indicating, say, the beginning of a turn) could be transferred between trackers and used to advantage by both. Similarly, when a potential conflict situation is detected, relative position and closing rate information, which is relatively insensitive to bias errors, could be derived from multiple sensors without the need for accurate registration error correction.

(f) Synchronization of interrogations. This is the third and most complex fix which employs fruit returns to advantage, rather than accepting them as a nuisance. This fix requires synchronism of interrogators in such a way that returns due to the various interrogators can be time-division demultiplexed. One way in which this could be done might be to employ a common prf (substantially lower than that used presently), and time share each interrogation interval among several interrogators; scanning could be either synchronized (with appropriate fixed heading angle offsets) or asynchronous. Interrogation scheduling would be such that all returns due to a particular interrogation would be received by all I/Rs before the next interrogation (by another I/R). Alternatively, interrogations could be dynamically programmed to prevent garbling; as the over-all prf grows, in areas of high I/R density, this might rapidly become quite complex.

(g) Combine the digital processing and tracking functions. Many of the fixes described in this and previous sections imply a much closer relationship between the signal processing and target tracking functions than is presently employed. The design philosophy of most present-day digitizers has evolved from the time when their primary function was to convert radar video into an information flow requiring far less bandwidth in order to gain economy of transmission from remote radar sites to centralized control centers. Concepts in which partial tracking is accomplished at the sensor site and additional tracking is performed at the center have been investigated in the DABS development program. This type of redefinition of the functions of the two locations appears appropriate for ATCRBS as well, and it should be done in a fashion compatible with the DABS ground computation network chosen for ultimate implementation.

E. Communications (Subtask A.3)

Work on this subtask was started toward the end of the reporting period. A comparison is being made between the proposed multichannel (VHF) data link independent of surveillance, and a DABS-based data link.

Three systems are to be examined from a technical, operational, and economic point of view:

(1) A system in which a VHF data link provides ATC communications to both air carrier and general-aviation aircraft. The VHF data link would also be utilized by air carriers for company communications.

(2) A system in which general-aviation aircraft are served by a DABS-based data link for ATC messages, and air carriers by a VHF data link for both ATC and company communications.

(3) A system in which both air carrier and general-aviation aircraft employ a DABS-based data link for ATC messages. Air carriers would also use a VHF data link for company communications and, possibly, for some extended-length, low-priority, ATC-related messages.

Tentative system designs will be carried out for the three alternatives in order to evidence the technical, operational, and economic consequences of each choice. Whenever possible, these system designs will utilize information derived from previous and current studies of the proposed data links.

F. Surveillance and Communication System (Subtask A.4)

Some aspects of the surveillance system have been studied and are reported below. Present effort is to configure the possible beacon and radar improvements in surveillance systems and to study their capability. This work will lead to recommendations on improvements that will ease the transition to DABS, as well as clarify the relationship between DABS and other possible evolutionary improvements to the surveillance system.

1. Usefulness of Primary Radar for Storm Detection

A preliminary study was made of whether primary radar should be used for detecting severe weather cells. It was initially hoped that signal Doppler spectrum would aid in detecting turbulence. However, the consensus of opinion among "weather experts" is that wind shear would produce the major contribution to the Doppler spectrum from a fan beam and that therefore turbulence information would be masked.

It has been proposed that primary radar have a stack of pencil beams which would decrease ground clutter and yield aircraft altitude information. The pencil beams would also measure altitude of a storm (which is correlated with turbulence) and determine how high an aircraft must fly to pass over the storm. If the pencil beams have Doppler capability, this may provide additional turbulence information. There is some promising turbulence-detection research being performed using a pencil-beam Doppler radar[12,13] at the Air Force Cambridge Research Laboratories.

The ASR and ARSR radars are not designed for weather detection (they operate at a relatively long wavelength and have no altitude capability). The question then is whether or not primary radar should be improved for weather detection. The radar return from a storm will frequently excessively clutter up the controller's scope. The "Production Common Digitizer" removes this clutter and the weather information. A "Weather and Fixed Map Unit,"[14] being experimented with by the FAA, appears to be a good fix to these problems and, in addition, provides the controller with improved weather information. The WFMU, by thresholding at two different intensity levels, generates a contour around the weather clutter and another contour around the severe storm cells. Altitude information is still lacking.

Our preliminary conclusion is that improvements to the primary radar for weather detection should be considered only if they are a cheap by-product of another requirement. Much weather data presently available is underused or inefficiently used. The National Weather Service maintains an extensive network of pencil-beam weather radars which provide storm cloud altitude information. Use of pilot reports would also provide cloud heights, temperature, winds, and visibility information. Orderly systems to collect and process weather information from the many different available sources should be investigated. Since controllers are not meteorologists, the information must be processed and presented in a simple usable form.

2. Safety Enhancement Derived from Primary Radar with Altitude-Measurement Capability

Three midair collisions in 1971 (Refs. 15-17), involving air carrier and general aviation aircraft, were examined to see what role, if any, the surveillance/communication system played in the accidents. The small aircraft were visible in all cases to the primary radar, and traffic advisories were issued to the air carrier. It appears that altitude information on the small aircraft obtained from the primary radar would have provided improved advisories and possibly prevented the collisions.

The Near Midair Collision Report of 1968 (Ref. 18), which covered 1128 near-miss situations, reported that traffic advisories materially assisted in avoiding hazardous situations. This report described the most hazardous flight regimes as those where traffic density is high, aircraft are changing altitude, and unknown traffic is present. The terminal area, especially a primary airport surrounded by satellite general aviation airports, provides just such an environment. Reference 19 cited Atlanta as having significantly fewer near-misses in relation to other comparable primary airports and attributed the existence of "Stage III advisories" as being the cause With automatic radar tracking of unequipped aircraft, an effective Stage III advisory service can be provided and with radar altitude information available advisories can be significantly upgraded and provide a safer system.

The above considerations prompted an investigation of the various ways of obtaining altitude information from primary radar. The following list is ranked according to decreasing implementation cost.

(a) Replace the ASR antenna with an S-band array with transmit and receive capability.

(b) Replace the ASR antenna with an AN/TPS-60 or AN/TPS-43 type array rotator.

(c) Modify the ASR by adding a stationary receive-only array in the vicinity of the ASR.

(d) Modify the ASR by adding a receive-only array rotator.

(e) Modify the ASR by adding a receive-only array or array rotator with a fan beam in azimuth and pencil beam in elevation.

In considering improved or new radars, note that at some satellite airports located in transition regions between en route and terminal coverage, these radars might act as gap fillers and, in addition, provide sequencing and spacing (Stage II advisory service).

3. Beacon System

This effort, together with the studies of the primary radar system, will eventually lead to specific recommendations for an integrated surveillance system, as explained in Section II-A.

An initial attempt has been made to form the many fixes of the beacon system, discussed in Section II-D, into promising system concepts.

4. System Costs

A preliminary examination of surveillance and communication equipment costs has been started in cooperation with appropriate FAA branches.

III. PRIMARY RADAR (ASR IMPROVEMENT PROGRAM, TASK B)

A. Introduction

Goals of this task are:

(1) Definition and demonstration of improved primary radar capability necessary to ensure that the enhanced ARTS-III ATC system will operate smoothly and reliably without controller intervention,

(2) Development of performance versus cost relationships involved in implementing such improved radar capability.

Subtasks required to achieve these goals are: determination of suitable radar concepts, definition of a "compatible configuration" of radar and ARTS-III satisfying one of the concepts, preparation of a technical description of the improved system, and modification of an existing radar to demonstrate the concept. "Suitable radar concepts" are those which will provide a detection capability and freedom from false alarms under all environmental (clutter) conditions with sufficient data produced on each target being tracked so that aircraft whose tracks cross are not confused.

B. Preliminary Definition of Improved Radar

1. Proposed Features of ARTS-III Compatible Radar

The clutter study, described in the third QTS, has been completed. This study included examination of: (1) presently used ASR clutter rejection techniques, (2) related improvement programs under way in the FAA and in the military services, and (3) state-of-the-art improvements which could conceivably be applied to the primary radar clutter problem. From this study has emerged a set of possible solutions for the various clutter situations. One group of these solutions, as shown in Table II, has been selected to form the basis of an ARTS-III-compatible radar. Major improvements in clutter performance will be embodied in this radar by the use of

TABLE II

FEATURES OF IMPROVED RADAR (S-BAND)

System Feature	Resulting in Improved
1. Two prf's per dwell time	Blind speed performance and track association; detection of ground vehicles
2. Linear optimum processing, quadrature video detection, ground clutter map	Discrimination against ground clutter and weather clutter; detection of aircraft flying tangential tracks
3. STC with R^{-4} law	Discrimination against bird clutter
4. Circular polarization	Discrimination against weather clutter
5. Nearly uniform antenna elevation gain pattern	Bird clutter performance; detection of high-altitude aircraft
6. Dual antenna beams	Long-range, low-elevation detection

advanced signal processing techniques, adaptive thresholding, range ordered sensitivity control (STC), and antenna beam shaping in elevation. Future work under this task will concentrate on a demonstration of the signal processing techniques and the measurement of aircraft velocity.

The antenna improvements noted in Table II, while important, are either already understood or are being investigated at NAFEC (e.g., dual antenna beams) and therefore will not be implemented in the demonstration radar.

2. Operation of Improved Radar

a. Staggered Prf

It is proposed that two sets of eight pulses be transmitted alternately at prf's about 10 percent apart at a radar antenna rotational rate of 10 rpm. This will remove blind speeds and provide a method of removing Doppler ambiguities. In addition, the eight complex samples can be examined for nonlinearities by observing if any reach the limit level of the A/D converters since the system would be designed to be linear up to this level. If nonlinearities are detected among the eight samples, no detections would be allowed in that range gate. Secondly, by processing this way, azimuth can be broken up into groups (as well as range) in deciding whether to apply circular polarization. In fact, signals from the thresholding device described below would be used to decide whether rain is present in each sector. This information would be fed to a small memory used to control the sense of circular polarization used in each sector on the next scan. A further advantage to staggered prf over constant prf, when a klystron is used, is the elimination of second-time-around clutter effect.

b. Improved Signal Processing

Refer to Fig. 2 for a block diagram of the proposed signal processor. Samples from eight pulses are collected and stored in the input shift registers to 10-bit accuracy. These registers

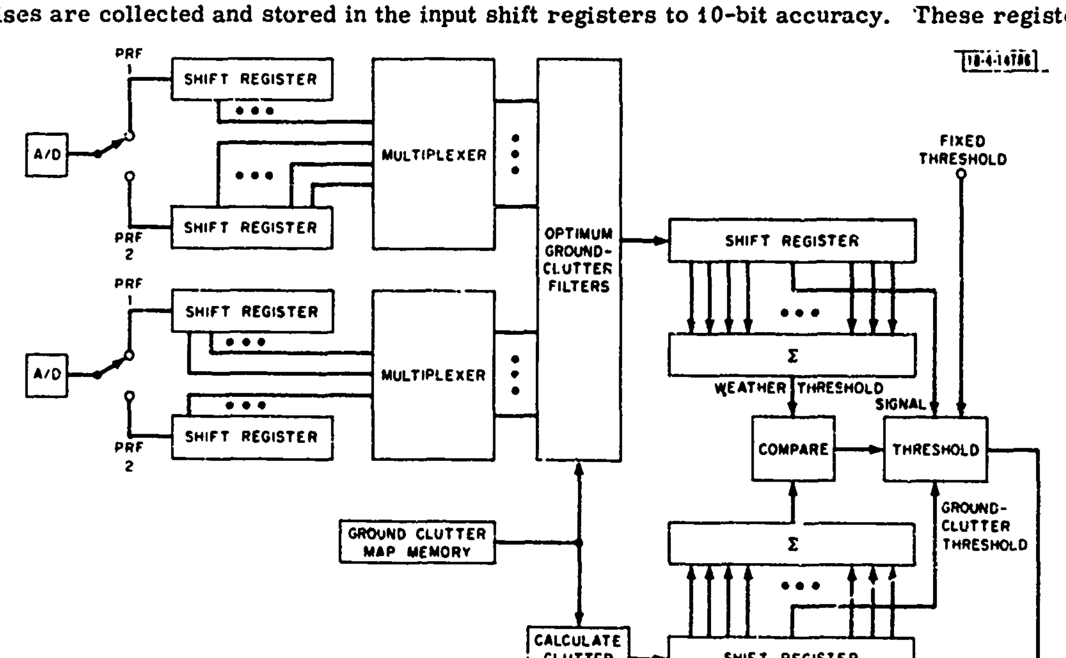


Fig. 2. Signal processor configuration.

are tapped in such a way that all data from one range gate enter the optimum ground clutter filters[2] together.

The ground clutter "map" remembers the level of clutter in every range-azimuth resolution cell. Its data are fed to the ground clutter filter so as to select the set of filters appropriate to the clutter level. Eight overlapping Doppler filters are implemented for each range gate. The rest of the circuit in Fig. 2 calculates appropriate thresholds for each type of clutter. The largest threshold is applied to determine the presence of a target.

For birds, the fixed threshold applied. The radar uses an STC which follows an R^{-4} law so the fixed threshold (based on the receiver noise level) corresponds to a fixed square meter target (say 0.2 square meter).

For weather, the upper shift register and summer calculate a threshold based on the clutter level in the corresponding Doppler filter of 14 or 15 nearby range cells. In this way, the threshold is raised only on those Doppler filters (one or two out of eight) which contain weather clutter. With the alternation in prf's, the target filter position moves so there is good likelihood of the targets being detected on at least one prf even in heavy precipitation.

The corresponding ground clutter levels are stored in the lower shift register. The central tap gives the ground clutter value for the range-Doppler cell being examined. A sum exactly similar to that being generated for weather is calculated and compared to the weather threshold. Since this sum is derived from a ground clutter map made in the absence of weather, the comparison will decide whether or not weather clutter exists in this region. If weather is absent, the ground clutter threshold will apply. This determination can also be used to set the antenna polarization on successive scans.

In this system there is no distinction between normal and MTI video. Since each target signal is coherently integrated over eight pulses, video interrogators (or enhancers) are of no value and there is no question of choice between normal and MTI. Even zero velocity (tangential) targets are processed as well as possible and are seen if their signal levels are sufficiently above the clutter.

Target reports would contain amplitude, range, azimuth, and apparent Doppler. In a tracking computer, part of the ARTS-III, these reports would be processed to remove Doppler ambiguities, track targets, and disregard targets which are probably surface traffic because of their low radial velocity and their position on known roads.

The diagram (Fig. 2) should be considered as schematic only. Analysis so far shows the feasibility of the processor and that it is within a reasonable cost budget. Final configuration will be determined by detailed hardware design and real-time simulation on the Laboratory's Fast Digital Processor (FDP).

C. Demonstration of Concepts

Phase I of the radar concept demonstration calls for demonstration of the improved signal processing concepts described above using the Laboratory's Fast Digital Processor (FDP). This is a versatile, programmable signal processor capable of about 25 million instructions per second. During this phase, an AN/FPS-18 klystron-type radar will be installed at the Laboratory and modifications will be made to improve its stability, to provide staggered prf, to add antenna digital control and digital position readout, and to provide connections to the FDP. An ARTS-III display will be used in conjunction with a small computer (Raytheon 706). Processing described in the previous section will be performed by the FDP over a 45° sector of azimuth coverage, and

experimental studies will be performed to determine the performance of the radar in different clutter environments.

During Phase II, a special-purpose digital signal processor will be designed and constructed using results of Phase I. The special-purpose processor will be capable of processing the full 360° coverage of the radar out to 48 nautical miles range.

IV. MEASUREMENTS ON SWITCHING ANTENNAS (TASK C)

A. Test Objectives and Accomplishments

Primary interest in this series of beacon tests is the effect of switching between dual airborne antennas upon automated tracking performance. Although it is the effect of the cycling upon the continuity or "smoothness" of tracking that is to be assessed, useful information will also be gained by comparing the effects of particular antenna installations, antenna switching schemes, antennas, and aircraft maneuvers.

As imposed, this task gives Lincoln Laboratory the responsibilities of planning, coordination, data reduction, data analysis, and reporting. Coordination responsibility includes that activity required to select test sites, identify test aircraft, and participate in the actual tests.

Activities this reporting period have included:

(1) Preparation and submission (June) of a preliminary test plan for flights by DOD aircraft against an ARTS-III equipped terminal.

(2) Preparation and submission (July)[19] of a preliminary test plan for flights by DOD aircraft against a NAS Stage A equipped simulated ARTCC facility.

(3) Study of real-time tracking data recording, and off-line data extraction and reduction techniques.

(4) Assessment of the appropriateness and feasibility of using numerous ARTS-III terminals (ORD, DCA, MIA, DEN, and IAH) and NAS Stage A en route centers (Jacksonville and Leesburg, Virginia).

(5) Visits to Jacksonville, Leesburg, NRL, and NAFEC.

(6) Coordination and management of preliminary flight tests taking place on 25 July 1972 in the Andrews AFB/Washington area (ARTS-III equipped).

(7) Coordination and management of preliminary flight tests taking place on 8-9 August 1972 at NAFEC, Atlantic City (using the Elwood ARSR/ATCBI site; NAS Stage A equipped).

B. Description of Tests and Test Results

The preliminary flight tests flown against the selected ARTS-III and NAS Stage A sites are summarized in Tables III and IV.

Data reduction for quantitative results from both of the preliminary flight tests is not yet completed.

Qualitative observations following from these tests are summarized below:

(1) The importance of complete and detailed planning, adequate AGA communications and selective data reduction was underscored.

(2) As predicted, the Andrews/Washington National area provided an adequately instrumented ARTS-III terminal in a good arrangement for beacon testing in a busy environment.

(3) En route testing using the NAFEC/Elwood sites provided dedicated and specialized equipment. However, the procedure for extracting beacon replies placed significant additional loads on personnel and the already fully committed NAFEC computers (7020 and 9020).

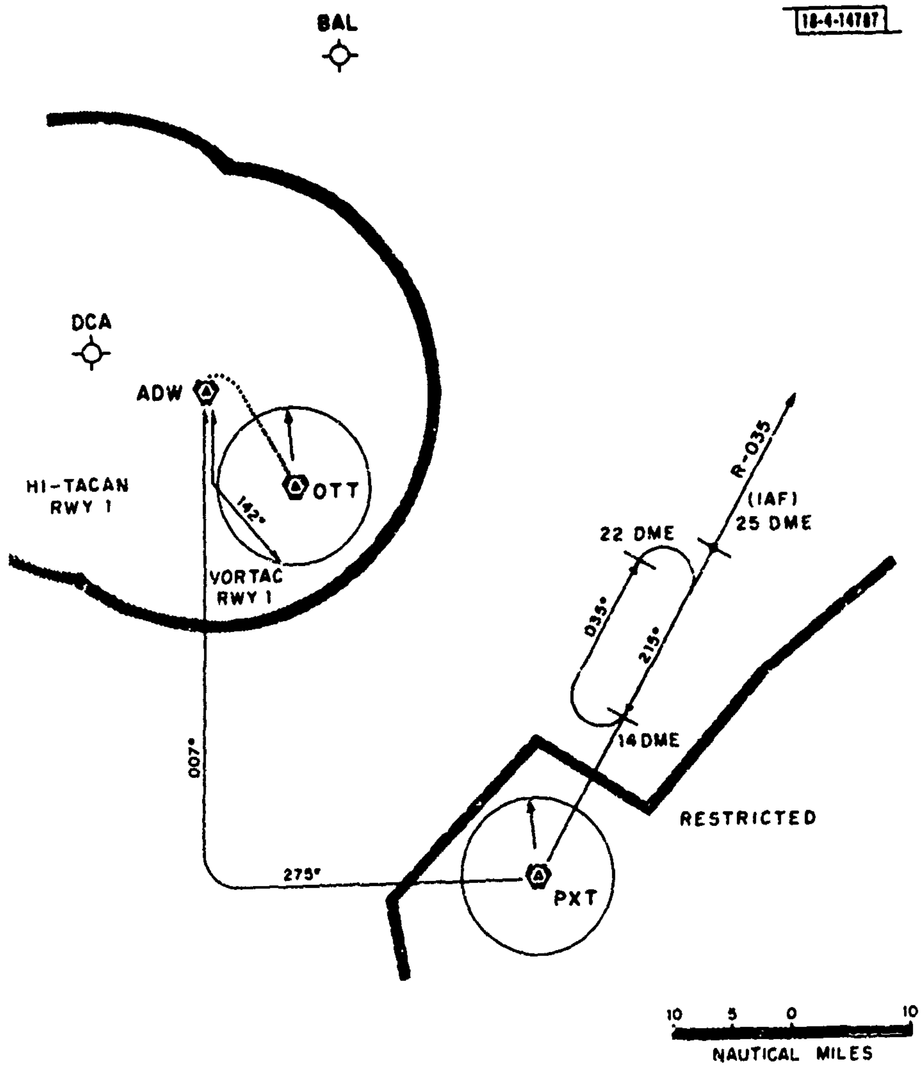


Fig. 3. Flight profile: tests at Washington National Airport.

(4) Observation of controllers' scopes at DCA and ADW showed numerous missed targets in each antenna configuration. Off-line data reduction at DCA was too slow to provide more than a few samples of data. (Each interrogation provides a line of printout such that a time consuming search process is required to obtain data from the one aircraft of interest.)

TABLE III

PRELIMINARY FLIGHT TEST AGAINST ARTS-III

Test Date	25 July 1972.
Test Location	Andrews AFB (ADW) and Washington National (DCA).
A/C Flown	T-39 (provided by Andrews Air Force Base).
Antenna Configurations	Bottom only, top only and cyclically switched between bottom and top.
Flight Profile	See Fig. 3 (simplified).
	Approaches and departures made at ADW to avoid interference with normal traffic at DCA. Profile consisted of a holding pattern at 16,000 feet at a distance of 30 n. mi., with 45° bank angle turns; an indirect approach and high-altitude penetration to ADW followed by a missed approach; a low-altitude ILS approach and a second missed approach. Maneuvers were reported via UHF communications.
Flight Duration	$2\frac{1}{2}$ hours.
A/C Equipment	VHF and UHF communications (duplicate headsets in rear compartment): full AIMS with Mode 2, 3/A, 4, or C selection.
Data Processing	All ATCRBS data from ADW transmitted via wideband link to the ARTS-III at DCA. Data processed per Data Extraction Program and recorded for subsequent reduction (five reels of tape collected).

C. Future Direction

A final test plan is being prepared for the next series of tests. This plan will count on the use of a greater variety of military aircraft types and will embody more efficient communications and data gathering techniques developed during the preliminary flights. Of particular importance will be the use of Coder-Decoder KY-614/GPA-122 to extract only those replies from the flight test aircraft.

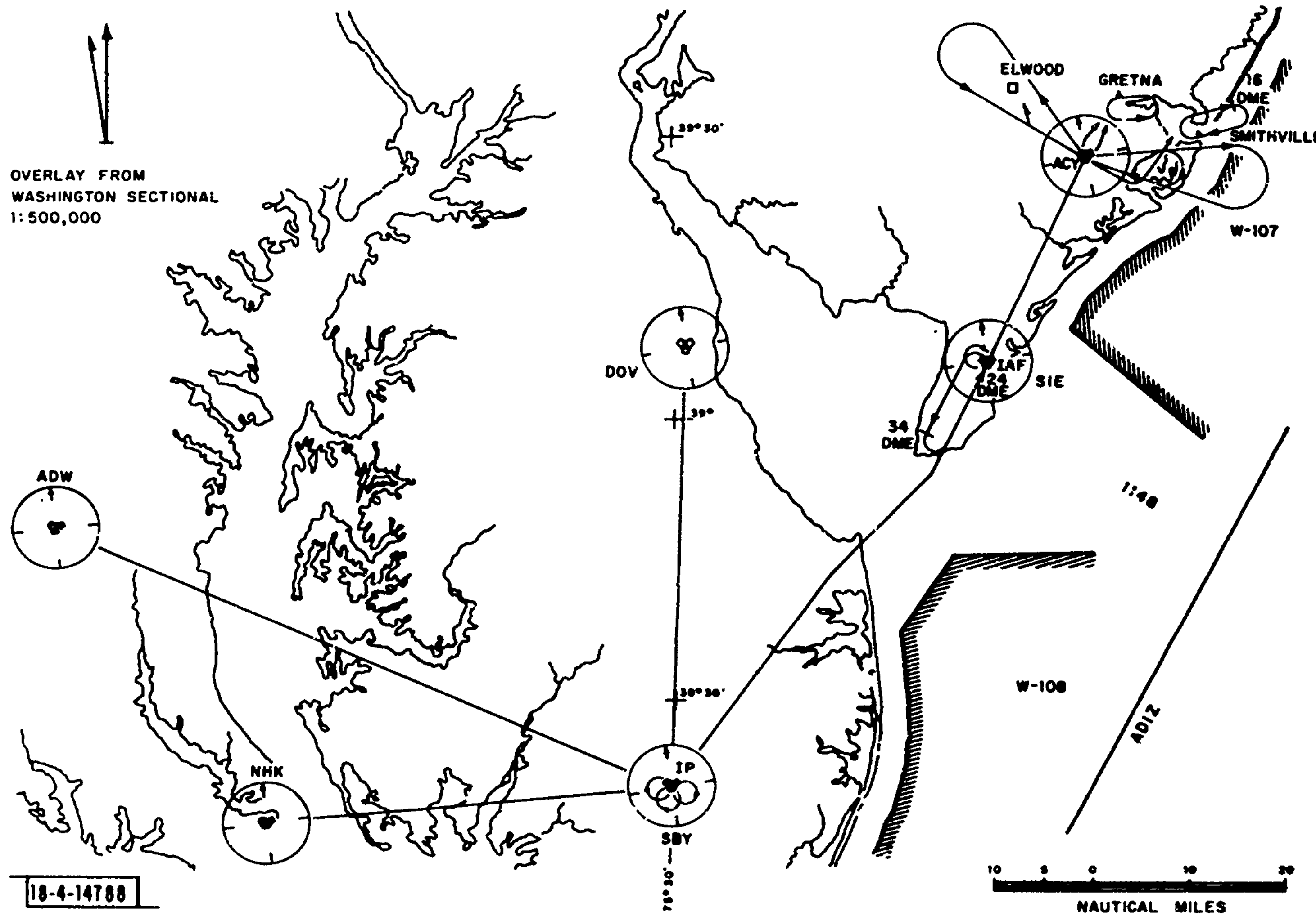


Fig. 4. Flight profile: tests at NAFEC.

TABLE IV

PRELIMINARY FLIGHT TEST AGAINST NAS STAGE A

Test Dates	8-9 August 1972.
Test Location	Atlantic City (NAFEC) and Elwood, New Jersey.
A/C Flown	EC-121 (provided by NRL).
Antenna Configurations	Bottom only, cyclically switched and diversity (Hartlobe).
Flight Profile	See Fig. 4.
	Included a number of 360° turns, both right and left, over the VORTAC at Salisbury, Maryland (SBY), 90 n. mi. distant, a holding pattern near SIE, 40 n. mi. distant; approaches to, from and holding patterns near Atlantic City (NAFEC).
Flight Durations	3-5 hours (each day).
Data Processing	See block diagram in Fig. 5.
	Raw video from search and beacon targets recorded on FR-950; FR-1800 recorded all target declarations from the common digitizer. IBM 9020 used to reduce these data off-line to provide scan-by-scan records of the A/C of interest; selected portions of tape are to be processed through the MLQ and IBM 7090.
	Also used 35-mm scope camera to take scan-by-scan photographs (back-up recordings).

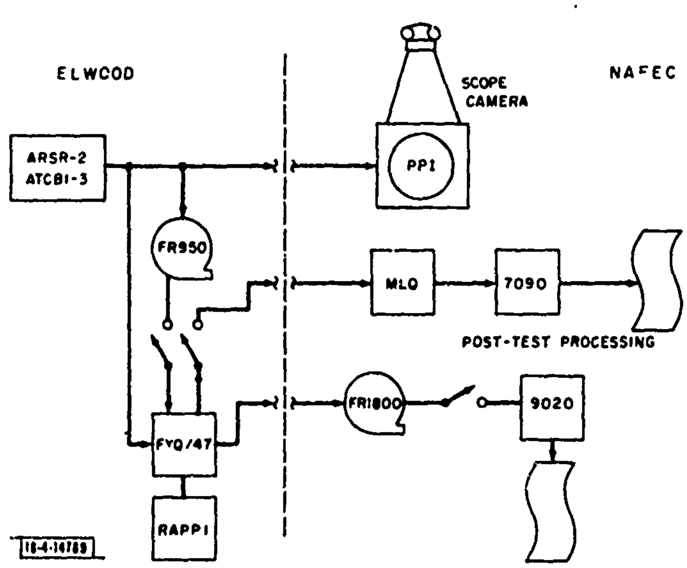


Fig. 5. Data processing at Elwood and NAFEC.

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ACRONYMS AND ABBREVIATIONS

AAFB	Andrews Air Force Base
A/D	Analog to Digital
ADW	Andrews Air Force Base
AIMS	ATCRBS-IFF-Mark-12 Systems
ARSR	Air Route Surveillance Radar
ARTCC	Air Route Traffic Control Center
ARTS	Automated Radar Terminal System
ASR	Airport Surveillance Radar
ATC	Air Traffic Control
ATCAC	Air Traffic Control Advisory Committee
ATCBI	Air Traffic Control Beacon Interrogator
ATCRBS	Air Traffic Control Radar Beacon System
BAL	Baltimore
CONUS	Conterminous United States
DABS	Discrete Address Beacon System
DCA	Washington National Airport
DOT	Department of Transportation
DVOR	Doppler VHF Omnirange
FAR	Federal Aviation Regulation
FDP	Fast Data Processor
IPC	Intermittent Positive Control
ILS	Instrument Landing System
IOP	Input-Output Processor
MAP	Missed Approach
MLQ	Multi-Level Quantizer
MTI	Moving Target Indicator
NAS	National Airways System
NAFEC	National Aviation Facility Experimental Center
NRL	Naval Research Laboratories
NWS	National Weather Service
PCD	Production Common Digitizer
PVOR	Precision VHF Omnirange
PRF	Pulse Repetition Frequency
RAPPI	Radar Plan Positive Indicator
S/C	Surveillance and Communication
TA	Terminal Area
TACAN	Tactical Air Communication and Navigation
TCA	Terminal Control Area
VHF	Very High Frequency
VORTAC	VHF Omnirange with TACAN
WFMU	Weather and Fixed Map Unit